Review of existing ILC magnet lists

V. Kashikhin for ILC Magnet Group

April 25, 2006

Main Linac quadrupoles

ILC International Linear Collider

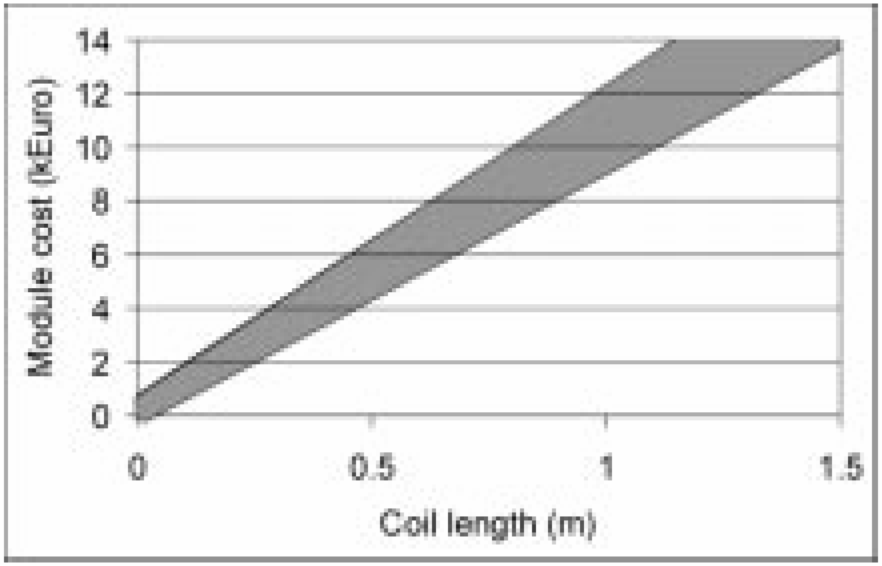
Magnet Design Input to the Magnet Systems	
Lattice	
Beamline name (location of use)	Electron/positron Main Linac
Quantity required	2*214 = 428
Magnet type (main harmonic)	Quadrupole
Integrated Strength of field	36 T
Effective length or max/min field constraint ?	0.6m
Layout [center(X,Y,Z), Slot length]	0.66m
Sagitta for dipoles (value, tolerance - if required)	N/A
Stage 2 (1 TeV CM) requirements	same
Field strength	54 T/m
Effective length or max/min field constraint ?	0.6m
Magnet Characteristics	
Bore diameter or full gap (x,y apertures)	dia=90mm(pipe dia=78mm)
Reference radius (to define 'good field' region)	5 mm
Normal/superconducting?	Superconducting
Field Tolerances:	
on main component (for magnets in strings)	2e-5 (<1ms), 1e-3(>0.2sec)
on multipole components	<3.e-4 at reference radius
Limit on maximum field/pole tip field ?	
Additional magnetic component(s) (e.g., trim coils if integrated with main harmonic)	skew, dipole corrector (if integrated)
Integrated Strength of field(s)	0.1 Tm
Tolerance on multipole components	

Alignment Tolerances (installation)	
position (magnetic center)	0.3 mm rms
pitch, yaw, roll (magnetic axis)	0.3 mrad
Alignment Tolerances (beam based)	
position (magnetic center)	~ 1 um
pitch, yaw, roll (magnetic axis)	<0.3 mrad
Method: steering dipole or magnet mover	dipole/skew steering
Operational characteristics	
Field: nominally constant or varied?	Constant
If varied, what field range & dB/dt	
For kickers: rise time and flattop duration	
Unipolar or Bipolar	Bipolar
Individual control or series ('string')	Individual

R&D to investigate magnetic center stability during -20% field change and possible coupling effects with trim coils.

LHC Correctors Cost in 2002

Cost includes materials, tooling, fabrication and cold testing (4.2 K). Presently contracts have been placed for all the corrector magnets through tendering procedures all over Europe. A study, made to see if the cost could be related to any of the magnet parameters, showed that surprisingly the cost correlates best with the length of the magnets. Fig. shows an area that covers the cost of the modules of the 8 magnet types that have been ordered in numbers greater than 100. The costs are ex-works and include materials, work, tooling, inspection, magnetic measurement at room temperature and a training test on each magnet module at 4.2 K. It does not include the support structures. The cost appears to be relatively independent of the wire type, the thickness of the coils and the number of the coils per magnet, the latter being a function of the multipole type of magnet. The cost of the superconducting wire represents typically 10% of the total magnet cost.



Cost of the magnets (modules) as a function of their lengths

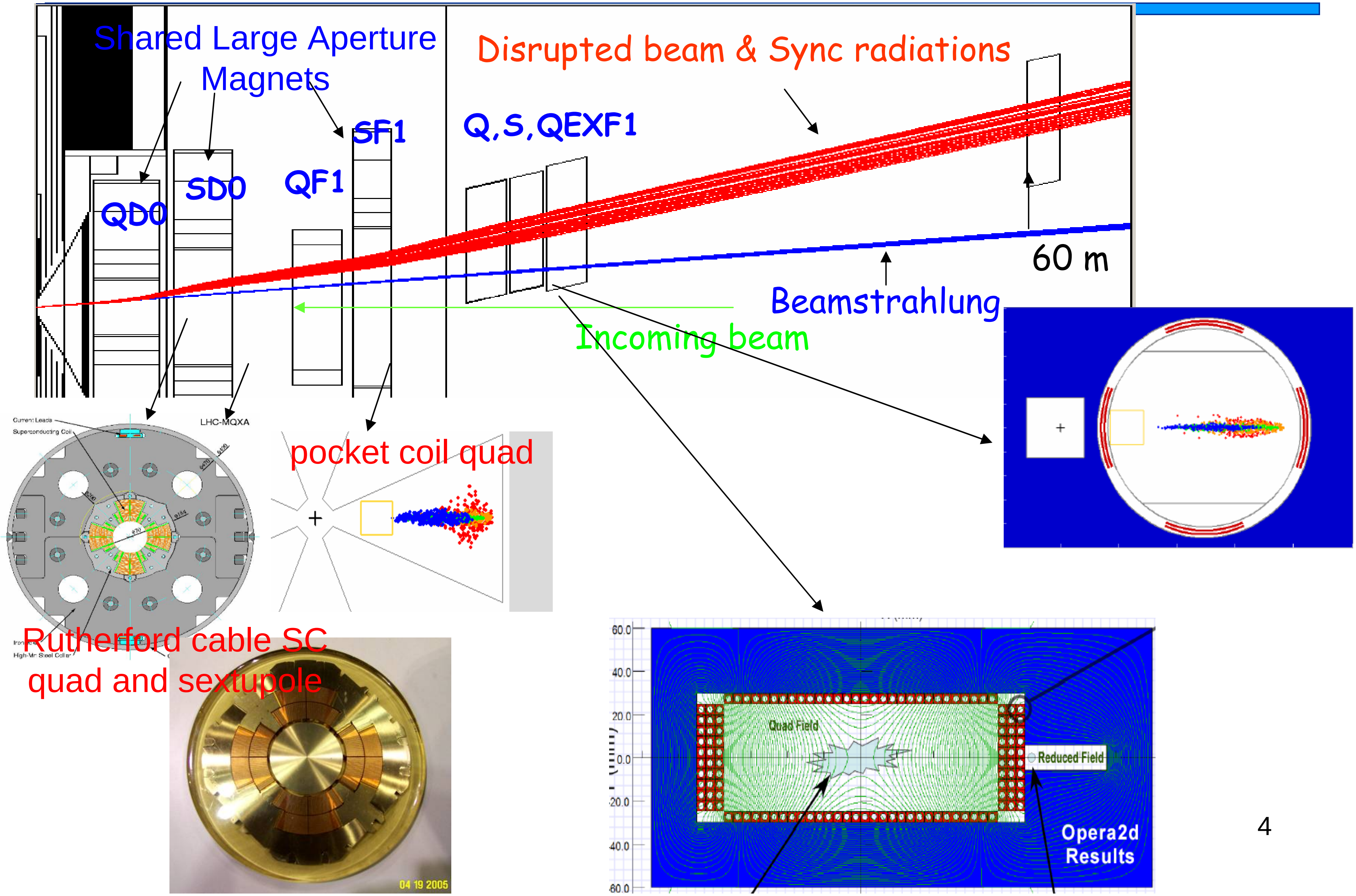
ILC Linac Quadrupoles at

10-20k$/magnet will cost

500 x 20k$ = 10 M$

ILC International Linear Collider

Conceptual design of 2mrad IR



ILC International Linear Collider

2 mrad IR magnets

Element	Start z, m	End z, m	Comments, type
BPM	~4.2	~4.4	X/Y directional stripline BPM, aperture R=35mm
QD0	4.5	7.0	SC quadrupole, with dipole X/Y corrector and skew quad corrector
SD0	8.195	11.995	SC sextupole, with dipole X/Y corrector, skew sextupole corrector and octupole corrector
Kicker	~12.5	~13.5	X/Y kicker, 100nsec rise time, max kick 100nrad
QF1	15.87	17.87	Iron pocket coil quadrupole
SF1	18.38	22.18	SC sextupole, with dipole X/Y corrector, skew sextupole corrector and octupole corrector
Collimator	~34.3	~34.6	Protecting collimator in front of first extraction quad
QEX1A	34.68	37.68	First septum quad, warm Panofsky style or SC super septum quad

Magnet type	Bore Radius mm	Field at Bore radius, T	Effective length, m	Qty
Quadrupole QD0	35	5.6	2.5	2
Sextupole SD0	88	4.0	3.8	2
Quadrupole QF1	10	0.68	2.0	2
Sextupole SF1	112	2.12	3.8	2
Septum Quadrupole QEX1A	113	1.33	3.0	2

2 mrad IP R&D

R&D, prototypes required:

1. Super septum and Panofsky quadrupoles
2. Large aperture sextupoles [final doublet quadrupoles including pocket coil quadrupole need to be mentioned in IR magnets section of the BCD]
3. Detector integration of large aperture quadrupoles and sextupoles within the detector [based on the feedback on detector opening procedure].
4. Study possibility to integrate feedback BPM into FD and detect its signal in presence of large offset and of the incoming beam.
5. Integration of the large aperture feedback kicker into FD.
6. Design tungsten liner for QD0, to reduces energy density due to radiative Bhabhas [this should appear in IR magnet section]

Further Studies :

1. Generate a table of tolerable beam losses and radiation loads on superconducting and conventional magnets
2. Optimization of the extraction optics and collimator designs to minimize the losses on the extraction line magnets
3. Possible range of 3.5m<L*<5m
4. Orbit and angle correction at the IP
5. Include solenoid field in to the simulations: at 4.5 from IP (start of QD0), the Bz field is

SiD: 5.6773000e-001 T

GLD: 1.5116628e+000 T

LDC: 2.6143399e+000 T

6. Design final doublet with QD0 gradient of 250T/m based on the Nb3Sn technology
7. Mitigation of radiation loads on incoming and outgoing beam SC magnets

ILC International Linear Collider

Positron Source Quadrupoles

Locationb	Energy Range	Magnet Type	B-field[a]	id	B/G	Quad Spacing	Quantity
	MeV		kG	cm	T,T/m	m	
ELTU+EULT	150,000	quadrupole	1000	1	20	7 (l=5m)	85
EUND	150,000	quadrupole	575	1	11.5	12.3 (l=5m)	20
ELTU+EULT	150,000	dipole	1.6	1	0.16	2.25(length)	112
ELTU+EULT	150,000	sextupole	0.1	10		0.035 ($L_{effective}$)	16 (k2=0.6-7 T/m^2)
TAPA+TAPB+KAS	1-38	solenoid	5	36	0.5	1.3(length)	6 x1.27 m long[b]
TAPA+TAPB+KAS	38-125	solenoid	5	31	0.5	4.3(length)	9x4.3 m long[b]
PPA	125-400	solenoid	2.5	31	0.25	4.3(length)	24x4.3 m long[b]
PBSTR	400-1135	quadrupole	8.5-24	7.4		1.95	24 quads in cryostat
PBSTR	1135–2605	quadrupole	6.8-15.6	7.4		6.9	12 quads in cryostat
PBSTR	2605-5000	quadrupole	8.8-16.8	7.4		12.3	12 quads in cryostat
PBSTR	1135, 2605	quadrupole	20	7.4		-	8 quads, matching[i]
PTRAN+PPATEL	400	quadrupole	2.0	15.4	1.0	8.4 (l=0.2m)	~3000 quads[c]
PTRAN+PPATEL	400	dipole	10[e]	15.4		0.43 (length)	~6 bends[c]
PTRAN+PPATEL	1135	quadrupole	2.0	15.4	1.0	23.7 (l=0.2m)	~1000 quads[c]
PTRAN+PPATEL	1135	dipole	10[e]	15.4	1.0	1.2 (length)	~6 bends[c]
PCAPA+PCAPB+KAS	125	quadrupole	3.3	15.4		1.6	~61 quads[d]
PCAPA+PCAPB+KAS	125	dipole	2[f]	15.4	0.2	0.26 (length)	8 bends[d]
PLTR	5000	quadrupole	40	7.5		6.5	~45 quads[g]
PLTR	5000	dipole	2.9	7.5	0.29	1.0 (length)	8 bends[h]

Positron Source Magnets

(a) $\int gdl$ for quadrupoles, B_{pole_tip} for dipoles, B_{pole_tip} for sextupoles, and B_z for solenoids,
(b)Quantity includes 2 primary and 1 bypass target capture regions
(c)Transport line magnets: beam energy is either 400 MeV or 1.135 GeV, tbd
(d)125 MeV e^+/e^- separator/target bypass optics, includes 2 primary and 1 bypass target capture regions
(e)Required bend angle is 0.322 rad; the listed pole tip field is a suggestion
(f)Required bend angle is 0.119 rad; the listed pole tip field is a suggestion
(g)LTR quads: 1 cm σ at 5 GeV and $\gamma\varepsilon$ = 0.045 m-rad.
(h)Required bend angle is 0.140 rad; the listed pole tip field is a suggestion, LTR
(i)Not necessarily in a cryostat.

RTML Quadrupoles

Name	Count	Type	Leff	Integrated Strength	Gradient,T/m	Serial Name	Constraint	Xgap	YGap	Radius	NC/SC
SCS_SQ1	1	Quad	0.1	0.6	6	QRTML1	No	0.02	0.02	0.006667	NC
QDSCS1	3	Quad	0.2	-5.986651406	-29.93325703	QRTML2	No	0.02	0.02	0.006667	NC
QFA	56	Quad	0.2	16.46931242	82.34656212	QRTML3	No	0.02	0.02	0.006667	NC
CQTURN1	2	Quad	0.1	0.6	6	QRTML4	No	0.05	0.05	0.016667	NC
QM014	1	Quad	0.15	14.04196309	93.61308729	QRTML3	No	0.02	0.02	0.006667	NC
QDA1	4	Quad	0.15	-16.56467848	-110.4311899	QRTML3	No	0.02	0.02	0.006667	NC
QMATCH8CM	1	Quad	0.666	-4.294607908	-6.448360222	QSCRTML1	No	0.075	0.075	0.025	SC
QMBCMLDFIX	1	Quad	0.2	-3.71149829	-18.55749145	QRTML6	No	0.06	0.06	0.02	NC
QFBCDL2	1	Quad	1	26.16130661	26.16130661	QRTML8	No	0.06	0.06	0.02	NC
QDBCDL3	1	Quad	1	-41.44618072	-41.44618072	QRTML7	No	0.03	0.03	0.01	NC
QFBCDL4	1	Quad	1	25.01730713	25.01730713	QRTML7	No	0.06	0.06	0.02	NC

Magnet System Cost Estimation

Cost estimation proposed approach:

1. **Define basic magnet prototypes with known at the moment cost break through**
2. **Scale up/down the cost for the same class of magnets**
3. **Use world average prices for raw materials**
4. **Use site specific costs: labor, electrical energy, LCW**
5. **Optimize general magnet and sub-system parameters**

- **Current density:**

  Conventional air cooled 1.5-2A/mm2?, water cooled 4A/mm2?

- **Maximum current**
- **Number of enclosures**
- **Number of magnet types**
- **Type of cooling**